PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Coaxial Electric Cables and Methods of Making Same

We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of Connaught House, 63, Aldwych, London, W.C.2, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to improved coaxial electric cables and to methods of making same. It is particularly directed to the providing of low-loss, noise-free instrument cables and miniaturised pulse cables suitable for use at elevated temperatures.

Instrument cables are finding increasing application in industry and it has been found difficult to obtain suitable cables for the transmission of the electrical impulses from the originating point to the receiving or recording instrument. This is because in many instances the voltages of the electrical signals to be transmitted are extremely minute and frequently difficult to distinguish from stray impulses and from spurious microphonic impulses generated within the cable itself. With instrument cables as known heretofore, particularly those made of rubber, the signals transmitted were often unduly distorted as a result of the disturbing noise voltage generated.

Furthermore, many applications of instrument cables require the use of small light-weight cables capable of operating at relatively high ambient temperatures. For example in transmitting the electrical impulses serving as a measure of power shock waves generated inside an internal combustion engine, a small, light-weight high-temperature cable is needed.

In addition to the growing need for non-microphonic instrument cables, the use of pulse cables has become of increasing importance in that the latter are at present employed as components of almost all radar installations. These cables function to transmit uni-directional pulses of very high peak voltage from one part of the radar equipment to another, such as between a modulator unit and an oscillator unit.

Heretofore, pulse cables made of rubber have been used. These pulse cables are of coaxial construction and comprise at least a centre conductor, a dielectric layer of a rubber compound, a thin layer of an electrically conductive rubber located between the centre conductor and the insulating rubber composition, and a surrounding metallic braid. The function of the conductive rubber is to prevent corona discharge from occurring at high pulse voltages between the dielectric surfaces and the inner conductor or braid. While these rubber pulse cables are satisfactory in some respects, they have certain marked deficiencies. For example, owing to the high dielectric loss of rubber and to the variation of its dielectric constant with frequency and temperature, these rubber cables unduly attenuate and distort the pulses they transmit, particularly when long runs of cables are used. In addition, the high dielectric loss of the rubber is responsible for some of the internal heating of the cable, and thereby the power-handling ability of the cable is substantially reduced.

It is suggested in Specification 739,962, that one means of overcoming the difficulties associated with the presently known instrument cables and pulse cables is by providing a cable construction using a semiconductive polyethylene layer over a polyethylene dielectric. This has proved to be a marked improvement over the rubber pulse cables used heretofore. However, we have found that a cable made up of a polyethylene semiconductive layer and

dielectric is unsatisfactory where high temperatures are encountered. This is because polyethylene is inherently incapable of operating at relatively elevated temperatures, failing at temperatures above 100°C. Thus where cables of an extremely small diameter are required, such as miniaturised pulse cables having an overall diameter of approximately 0.25 inches, difficulty is encountered in using polyethylene pulse cables. This is because the miniaturisation of the cable serves to concentrate any heat dissipater, and as a consequence the cables operate at much higher temperatures than standard-sized ones. In addition, pulse and instrument cables are often required to operate at relatively high ambient temperatures, such as in close proximity to jet engines in airplanes, and polyethylene type cables are unsuitable for such a use.

It is an object of the present invention, therefore, to provide a low-loss miniaturised coaxial pulse cable whose properties are consistent and uniform over a wide frequency and temperature range.

Another object is to provide a pulse cable whose attenuation of transmitted pulses due to dielectric loss is far less than in equivalent pulse cables at present commercially available.

Another object is to provide an improved low-loss noise-free instrument cable.

Another object is to provide a low-loss noise-free instrument cable or miniaturised coaxial pulse cable capable of continuous operation at temperatures as high as 200°C.

According to the invention there is provided a coaxial cable comprising an inner conductor and an outer conductor in which the insulating medium separating the inner conductor from the outer conductor is formed of a layer of polytetrafluoroethylene located between two semiconductive layers each composed of a homogeneous mixture of polytetrafluoroethylene and finely divided carbon one of said semiconductive layers being in contact with the outer surface of the inner conductor and the other semiconductor layer being in contact with the inner surface of the outer conductor.

The following descriptions of embodiments of the invention should be read in conjunction with the accompanying drawings, in which:

Fig. 1 is an elevation of a noise-free or pulse cable with the various layers making up the cable cut away to show the internal construction:

Fig. 2 is an elevation of another embodiment of the invention showing a cable having additional layers of metallic braid.

Fig. 3 is a schematic view, partly in section, of the equipment used for applying the polytetrafluoroethylene semiconductive layer of the cable.

The low-loss noise-free instrument cables and miniaturised pulse cables of this invention are of coaxial construction and, as shown in Figs. 1 and 2, are comprised of a centre or inner conductor 1, a thin layer 2 of an electrically conductive mixture of polytetrafluoroethylene and finely divided carbon, a dielectric layer of a polytetrafluoroethylene 3, another thin layer of conductive polytetrafluoroethylene 4, an outer conductor of braided wire 5 and a protective layer 6 of an elastomeric jacketing material or of polytetrafluoroethylene. As shown in Fig. 2 additional layers of braided wire 7 and 9 and insulating layer 8 may also be present.

In Figs. 1 and 2 the inner conductor 1 may be a solid conductor or formed of stranded wires. In addition to the braided wire layer 5 shown in Fig. 1, one or more additional wire braided layers surrounding the first one, either with or without an insulating layer between them, may be used for shielding purposes, as shown in Fig. 2. In Fig. 2, a second braid 7 is shown surrounding the first braid 5, and this may have around it a thin layer of insulating material 8, preferably wrapped as a polytetrafluoroethylene tape. Surrounding this insulating layer a third braid 9 is shown. This combination of braids and insulating layer as shown in Fig. 2, sometimes referred to as a "triaxial" type construction, is of value in installations where it is desired to use the third braid as part of an independent ground system. The metallic braids are usually made of silver-plated copper wire, although, to meet special requirements, such as improved shielding, magnetic stainless steel wire braids may be substituted for certain of the copper braids. In some cases also, a protective armour of metal braid is used surrounding the elastomeric jacket.

Although the basic structure shown in Fig. 1 is applicable both to pulse cables and noise-free instrument cables, the actual physical dimensions of each component part of the cable will vary according to the intended use.

Polytetrafluoroethylene has previously been used as a dielectric for a coaxial cable. However, attempts to produce a pulse cable having a semiconductive polytetrafluoroethylene layer, using known techniques, have been unsuccessful. Thus, the method of producing a polyethylene pulse cable, as disclosed in the previously referred to copending application, cannot be used for producing a polytetrafluoroethylene-insulated pulse cable. The properties of polytetrafluoroethylene in combination with

carbon black or colloidal graphite are such as to render it extremely difficult to extrude in the thin layers required for miniaturised cables. However, we have found that these difficulties in producing a semiconductive polytetrafluoroethylene layer may be overcome by the use of a dip-coating technique employing an aqueous co-suspension of polytetrafluoroethylene and colloidal graphite. The wire is alternately passed several times through the co-suspension and then through a conditioning oven until a conductive polytetrafluoroethylene layer of the desired thickness has been built up on the inner conductor. A suitable construction of wire-coating equipment for use in this dip-coating method is shown in Fig. 3. As shown therein, a pay-off spool 10 is fastened on one side of a shaft 11 which is mounted in a ball-bearing while the other side of the shaft carries a disc 12. This disc forms part of a friction device permitting adjustment of the tension of the unwinding wire. The travelling speed of this wire is controlled by a capstan 13 connected to a variable speed drive 14. The sequence is such that the wire leaves the pay-off spool, passes through a bath 15 containing a wetting agent, as well as a cleansing means, and then is guided by the sheave 16 in an upward direction through the first dip-coating container 17 which contains the co-suspension of polytetrafluoroethylene and graphite. From there the wire passes into the first heat-conditioning unit 18. This unit consists of a tubular oven consisting of an outer aluminium cylinder 19 and an inner tubing 20 of a borosilicate glass. This tube is provided with two heating coils forming an upper and a lower heating zone. The current flowing through each heating coil is independently controlled, thereby permitting the establishment of a temperature gradient within the heat-conditioning unit as well as allowing for adjustment of the overall temperature of the complete unit. Thus vaporisation of the water carrying the co-suspension is essentially completed in the lower zone and fusion of the coating takes place in the upper zone. The two zones of each oven unit are provided with short side tubes 21. These tubes are also made of borosilicate glass and extend from the main inner tube through the oven insulation 22 to the outside of the aluminium cylinder 19. These side tubes serve for inserting thermocouples into the respective heating zones. These thermocouples are used, in conjunction with an electronic thermoregulator, for recording and automatically controlling the temperature in the various units.

The aluminium cylinders are closed at both ends by pressed asbestos discs 23 provided with holes 24 for the passage of the wire. The discs serve to confine the asbestos oven insulation 22 and also to centre the inner borosilicate tube within the heat-conditioning unit. As the wire leaves the oven unit, passing over the upper sheave 25, it is guided to the next unit and so forth until it reaches the capstan 13 and the take-up spool 26. One of the principal problems associated with obtaining uniformly coated wires using the dip-coating method is the maintenance and control of baking conditions in the heat-conditioning unit, and the construction described above is convenient owing to the separate heat control of the two portions of the unit.

The semiconductive layers consist of an intimate, homogeneous mixture of polytetrafluoroethylene and graphite having a volume resistivity of less than 5,000 ohm/cm³. The percentage by weight of graphite present in this layer may vary from 15% to 60%. The co-suspension from which this semiconductive layer is deposited consists of a mixture in appropriate proportions of aqueous suspensions of polytetrafluoroethylene and colloidal graphite.

In the construction of a coaxial cable according to this invention it was found that, using the co-suspension of the preferred embodiment, the deposition of the conductive layer on the wire required five coatings to produce a semiconductive layer having a wall thickness between 0.001 and 0.002 inches. Such a five-coated layer had a volume resistivity of between approximately 100 and 500 ohm/cm³. It was found that semiconductive coatings prepared in the foregoing manner were exceedingly tough and could not be easily scraped from the wires or from the surface of the dielectric.

After the wire had been so coated, a layer of polytetrafluoroethylene was extruded over the semiconductive layer. It was found that conventional extrusion techniques in which the plastic material is rendered semifluid and then forced through a die over the wire, such as used for polyethylene, could not be used satisfactorily with the polytetrafluoroethylene. Instead it was preferred to use a paste type of extrusion employing a lubricated polytetrafluoroethylene. The polytetrafluoroethylene is brought to a pasty consistency by incorporating in it approximately 20% by weight of a relatively low-boiling purified light mineral oil. A more volatile lubricant such as naphtha may also be used, and is frequently preferable because it may be more readily driven off. The lubricated polytetrafluoroethylene is contained within a cylinder having a passageway for the

wire; a piston, having a driving mechanism, and also containing a wire passageway, is used to compress and extrude the lubricated polytetrafluoroethylene through a suitable die. This arrangement is referred to as a ram-type extruder. The oil must be vaporised completely before the polytetrafluoroethylene layer can be sintered; otherwise blistering of the surface or other flaws may occur.

Following the extrusion around the semiconductive layer of the polytetrafluoroethylene dielectric, a second semiconductive layer was deposited using the dip-coating method previously described.

The volume resistivities of semiconductive layers prepared in accordance with the dip-coating technique were found to vary within a range of 100-10,000 ohm/cm³. By increasing the percentage of finely divided carbon or colloidal graphite present in the co-suspension, the resistivity of the deposited layer could be reduced. Resistivity values below 5,000 ohm/cm³ are preferred. Thus a conductive plastic material whose resistivity value is less than 5,000 ohm/cm³ will fulfil its intended function of preventing corona discharge in a cable with high voltage pulses having rise times as short as 0.01 microseconds; it will also insure that the attenuation of pulse voltages having frequency components up to 30 megacycles is not excessive.

What we claim is:—

1. A coaxial cable comprising an inner conductor and an outer conductor in which the insulating medium separating the inner conductor from the outer conductor is formed of a layer of polytetrafluoroethylene located between two semiconductive layers each composed of a homogeneous mixture of polytetrafluoroethylene and finely divided carbon one of said semiconductive layers being in contact with the outer surface of the inner conductor and the other semiconductive layer being in contact with the inner surface of the outer conductor.

2. A coaxial conductor cable according to Claim 1 in which the semiconductive layers are composed of an intimate mixture of polytetrafluoroethylene and finely divided carbon containing from 40% to 85% by weight of polytetrafluoroethylene and from 60% to 15% by weight of finely divided carbon.

3. A coaxial conductor cable according to Claim 1 in which the semiconductive layers are composed of an intimate mixture of polytetrafluoroethylene and finely divided carbon approximately in the proportions by weight of 80% of polytetrafluoroethylene and 20% of finely divided carbon.

4. A coaxial conductor cable according to any of the preceding claims in which the outer conductor is a sleeve of braided metallic wire.

5. A coaxial conductor cable according to any of the preceding claims in which said semiconductive layers are applied by passing the body to be coated through an aqueous co-suspension of polytetrafluoroethylene and finely divided carbon.

6. A coaxial conductor cable according to any of the preceding claims in which the finely divided carbon is colloidal graphite.

7. A method of making a coaxial conductor cable as claimed in any of the preceding claims comprising the steps of applying to an inner conductor by dip-coating a semiconductive layer consisting of an intimate mixture of polytetrafluoroethylene and finely divided carbon, extruding an insulating layer of polytetrafluoroethylene to surround said semiconductive layer, applying by dip-coating a second layer of said semiconductive mixture directly surrounding said insulating layer and forming a tightly fitting sleeve of braided metallic wires surrounding said second layer of semiconductive material.

8. A coaxial conductor cable as described and illustrated in Fig. 1 or Fig. 2 of the accompanying drawing.

9. A coaxial conductor cable according to any of Claims 1-6 in which the semiconductive layers are applied by means of the equipment described in the Specification and illustrated in Fig. 3 of the accompanying drawing.

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1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

FIG. 1.

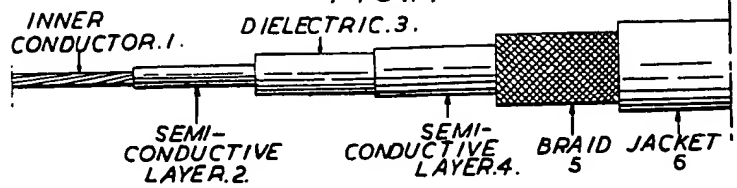

FIG. 2.

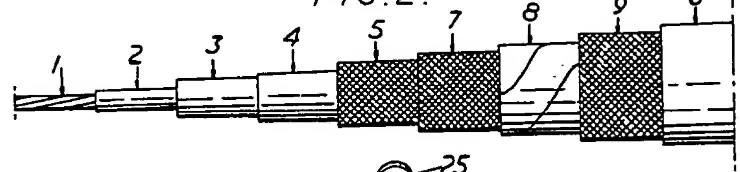

FIG. 3.